# *Synopsis*

This thesis consists of research work in the broad area of soft condensed matter theory with a focus on active matter. The study of long wavelength, low frequency collective behavior of active particles (bacterial suspensions, fish schools, motor-microtubule extracts, active gels) forms an interesting modification to liquid-crystal hydrodynamics, in which the constituent particles carry permanent stresses that stir the fluid. Activity introduces novel instabilities and many novel aspects emerge. Our works focus on the dynamics, order, fluctuations and instabilities in these systems. In particular, we investigated the dynamics, order and fluctuation properties emerging from effective hydrodynamic descriptions of translationally ordered active matter and also studied those in microwave-driven quantum Hall nematics. We also investigated the rheological properties of active suspensions subjected to an applied orienting field. A summary of the works carried out is as follows.

**Translationally ordered active phases – active smectics and active cholesterics:** Active or self-propelled particles consume and dissipate energy generating permanent stresses that stir the fluid around them. The collective behavior of systems of active particles, in systems with translational order, pose interesting questions and possibilities of new physics that differ strikingly from those in systems at thermal equilibrium with the same spatial symmetry. We developed the hydrodynamic equations of motion for (a) an active system with spontaneously broken translational symmetry in one direction, i.e., smectic and (b) the simplest uniaxially ordered phase of active chiral objects, namely, an active cholesteric. We analyze the fluctuation properties as well as the nature of characteristic instabilities that these systems can display and make a number of predictions. For example, in the case of an active smectic, we show that active stresses generate an effective active layer tension which, if positive, suppresses the Landau-Peierls effect, leading to long-range smectic order in dimension $d = 3$ and quasi-long- range in $d = 2$, in sharp contrast with thermal equilibrium systems. Negative active layer tension in bulk systems, however, lead to a spontaneous Helfrich- Hurault undulation instability of the layers, accompanied by spontaneous flow. Also, active smectics, unlike orientationally ordered active systems, normally have finite concentration fluctuations. Similarly, for the case of cholesterics we show that cholesteric elasticity intervenes to suppress some of the instabilities present in active nematics.

**Numerical simulation of active smectics:** We present results from a Brownian Dynamics simulation, with no hydrodynamic interaction, of a system of apolar active particles forming translational liquid-crystalline order in a suspension. The particles interact through a prolate-ellipsoidal Gay-Berne potential. We model activity minimally through different noise temperatures for movement along and normal to the orientation axis of each particle. We present preliminary results on the disruptive effect of activity on smectic order for the parameter values investigated. Future work will test the predictions of our theory [1] on active smectics.

**Rheology of active suspensions near field-induced critical points :** Shear induces orientation of active stresses in a suspension, through flow alignment. Depending on the sign, activity then either enhances or reduces the viscosity. The change in viscosity, in the zero frequency limit, is proportional to the product of the magnitude of active stress and the system relaxation time. A strong enough orienting field can make the system approach a critical point and the relaxation time diverges. We show that, this results in the divergence of viscosity at zero frequency making the system strongly viscoelastic. Depending on the sign, activity strengthens or reduces the effect of the field. We also investigate the rheological property of an active suspension with mixed polar and nematic oreder.

**Active quantum Hall systems:** We construct the hydrodynamic theory for a $2d$ charged active nematic with $3d$ electrostatics. We have investigated the interplay of the Coulomb interaction and activity in these systems. We show that activity competes to enhance the charge density fluctuations normally suppressed by long- ranged Coulomb interactions. The charge structure factor $S_q$ of the corresponding passive charged nematic goes to zero as $q$, whereas in charged active nematics, activity leads to a nonvanishing charge structure factor at small wavenumber. We also show how the effect of an applied magnetic field can be incorporated into the dynamics of the system and leave scope for further studies on these effects.